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(71) Applicant *(for all designated States except US)*: ZETETIC INTERNATIONAL LIMITED [GB/GB]; 200 York Road, Battersea, London SW11 3SA (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)* : JENNINGS, Christopher, Sorrel [GB/GB]; 18 Hillbury Road, London SW17 8JT (GB). CROSS, Thomas, Edward [GB/GB]; 3 Caxmere Drive, Wollaton, Nottingham NG8 1GG (GB).

(74) Agent: CRAWFORD, Andrew, Birkby; A.A. Thornton & Co., Northumberland House, 303-306 High Holborn, London WC1V 7LE (GB).

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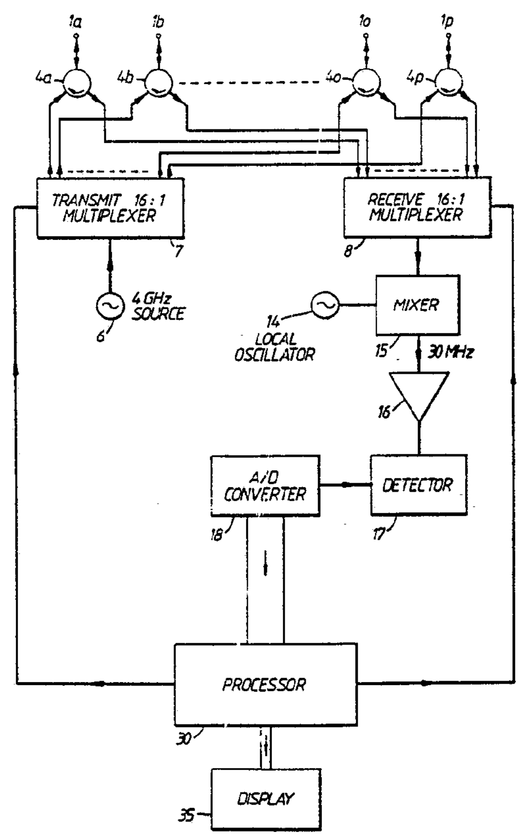
(54) Title: METHOD AND APPARATUS FOR SELECTIVELY DETECTING OBJECTS

(57) Abstract

A method and an apparatus for selectively detecting objects made of a particular type of material use an array of spatially separated aerials to define a detection region. Each aerial in turn transmits electromagnetic radiation at a selected frequency into the detection region and the radiation received at each of the non-transmitting aerials is measured. The complete set of measurements is representative of the contents of the detection region. The measured data is processed to provide information on the objects present in the detection region which are made of the chosen type of material.



METHOD AND APPARATUS FOR SELECTIVELY DETECTING OBJECTS

The present invention relates to the field of selective detection of objects made from particular types of material.

The invention finds application in detecting objects made of a selected type of material when present with and possibly hidden by material of a different type, e.g. in screening baggage for firearms, in the mapping of mineral seams, in locating buried pipes and in gall stone searches. The features of the invention will be described herein in relation to the embodiments used in metal detection for security purposes.

Metal detection for security purposes generally has one of two aims, either to detect the theft of metallic objects, such as quantities of precious metal, or to detect objects which could be used offensively, e.g. firearms.

Precious metal theft often involves the repeated removal of small quantities of metal which the thief conceals on his person before leaving the security area. Common security systems involve some measure of manual searching of persons/objects leaving the security area since existing metal detection systems have poor detection performance for light, small metallic objects.

Screening of personnel and baggage for offensive metallic objects, e.g. at an airport, usually uses an induction loop. The person/object passes through the

induction loop and any sufficiently large metal object on the person/object will alter the magnetic field, changing the induced voltage across the induction loop. This voltage change is used to signal the presence of metal on the person/object. Since no information is given about the location or size of the object passengers may be subjected to a search even when they are carrying innocent metal objects.

The present invention provides a method of selectively detecting objects comprising:

transmitting electromagnetic radiation into a predetermined detection region, detecting a parameter of the electromagnetic radiation at a plurality of spatially separated locations in the detection region, producing signals indicative of the values of the detected parameter, and processing said signals to produce further signals representative of the contents of the detection region.

The present invention also provides detection apparatus comprising:

a plurality of aerials operable in a transmitting and in a receiving mode and arranged to define a detection region, a source of electromagnetic oscillations, connected switchably to each of the aerials, control means for determining in which mode each of the aerials is to operate at a particular time and for connecting a selected one of the aerials to the source of electromagnetic oscillation, monitor means for producing signals indicative of a parameter of the electromagnetic radiation received by each aerial in the receiving mode, and processing means for producing further signals representative of the contents of the detection region from the output of the monitor means.

Preferably in embodiments of the invention used for metal detection the electromagnetic radiation is at

radio frequencies.

To monitor the presence, size and/or shape of a detected metallic object one need only measure the intensity of the received signals. The phase of the received signals provides information on the composition of the metallic object.

An advantage provided by embodiments of the invention is that the location of a detected metal object on a screened person/object can be found. Also small, light metallic objects are detectable using apparatus embodying the invention.

A further advantage provided by embodiments of the invention is that for screening people a low power may be employed (e.g. less than 0.01 watts) whereas for screening objects higher power embodiments may be used with simpler receiving circuitry.

Further features and advantages of the present invention will become clear from the following description of an embodiment thereof, given by way of example, with reference to the accompanying drawings, in which:

Figures 1 and 2 show diagrammatically how a received radiation intensity pattern is affected by metallic objects placed in an array of aerials in one embodiment of the invention;

Figure 3 shows a different arrangement of aerials in another embodiment of the invention;

Figures 4a and 4b show security systems incorporating a further embodiment of the invention: and

Figure 5 shows diagrammatically an arrangement of circuit elements suitable for use in the embodiment of Figure 4b.

Different types of material exhibit widely varying reflective properties towards electromagnetic radiation and those properties for each material vary with the frequency of the incident radiation. Embodiments of

the invention use the differences in reflectively between types of material at a particular frequency to selectively detect objects made of a chosen type of material. For metal detection, embodiments of the invention use the property of metals (as highly electrically conductive materials) to reflect radiation at radio frequencies whereas less conductive materials are poorly reflective at those frequencies.

In the embodiment shown in diagrammatic form in Figures 1 and 2, two facing banks each of four aerials 1 define a detection region 5, one aerial transmitting receiving at chosen frequency, in this example circa $4GH_z$, and the other aerials receiving the tranmitted radiation. Figure 1a shows the directional nature of the radiation from a dipole aerial The intensity of the wave radiated from such an aerial varies with the angle from the plane of the aerial according to equation (1):

$$\text{Intensity of the wave radiated at angle } \theta,\ I(\theta) \propto \sin^2 \theta \quad (1)$$

When aerial 1b transmits radiation, the aerial 1g receives the greatest intensity, then aerials 1h and 1f, with aerials in the same plane as the transmitting aerial receiving minimum or zero intensities.

Placing a metallic object 2 in the detection region 5 as in Figure 1b alters the pattern of received intensities. The metallic object reflects radiation so that aerials 1a and 1c receive increased intensities whereas aerial 1g has a drastic decrease in received intensity. Varying the particular aerial which is transmitting produces a different received intensity pattern as shown in Figure 1c (where aerial 1b is receiving and aerial 1c is now transmitting). The received intensity pattern is characteristic of the particular transmitting aerial, the location of the receiving aerials and the size and location of the metallic object 2 in the detection region

5.

Figure 2 shows how the received intensity pattern is also determined by the shape of the metallic object 3 in the detection region.

Metallic objects in the detection region 5 of the array of aerials can be effectively mapped in two dimensions by transmitting radiation from each aerial in the array in turn, and measuring the intensities at each receiving aerial when each different transmitter is in operation. The complete set of intensity measurements is characteristic of the objects in the detection region.

In general, metallic objects will not be passed through the detection region 5 of metal detecting embodiments in isolation, but will be concealed or carried by or on other objects or persons. The set of intensity measurements produced is characteristic of the whole object or person passed through the detection area. However, the non-metallic materials composing the object or person, which act to absorb and refract radiation, produce only small changes in the transmitted radiation at this frequency whereas the concealed or carried metallic objects act to determine the received intensity patterns to a relatively much greater extent.

Some element of mapping in three dimensions may be achieved in a number of different ways. One method which can be used is to have the person or object to be screened moved through the detection region while the whole mapping sequence is carried out a number of times. Several sets of intensity measurements would be produced each representing a different section through the screened person or object. Since embodiments of the invention can carry out one complete mapping sequence in 5 miliseconds a large number of sections could be taken through a person moving through the apparatus at walking pace.

Another way of obtaining information on the screened object or person in three dimensions is to use a number of banks of aerials to define a three dimensional detection region. Figure 3 shows such an embodiment where six banks of aerials define the detection region. The mapping sequence may be carried out in two different ways with a stationary person or object to be screened. The first way is to operate the aerials as three separate systems and to carry out 3 separate mapping sequences with the aerials 10, 11 and 12. The second way is to transmit from each aerial in the array in turn and to measure received intensities at all of the other aerials for each different transmitter.

In different embodiments of the invention the phase of the received signals may be measured in addition to or instead of the intensity.

Once the screening data has been obtained it is processed to provide useful information, the particular processing used depending on the application to which the apparatus is being put. More than one type of processing may be used in a single embodiment of the invention.

The complete set of screening data can be processed directly using a suitable algorithm to give information on the size, shape, mass and location of metal objects on the screened person/object. Alternatively the data can be processed by comparison with stored signals held in memory. Such processing can be performed in two ways termed Type I or Type II detection.

In Type I detection the sets of intensity measurements for the screened object or person are processed and compared with stored sets of intensity measurements obtained for the same object or person at an earlier time. If the metallic objects associated with the screened object or person have altered between the two screenings the system detects and indicates the change. The system

operator can then arrange to have the screened object or person searched manually. Type I detection could be employed to detect metal theft and to detect theft of confidential documents if these are produced on specially treated paper impregnated with metallic powder.

In Type II detection the sets of intensity measurements are processed and compared with stored sets of intensity measurements obtained by screening particular objects, such as firearms or their components. The processing and comparing is arranged to detect intensity measurements representing particular metallic objects within the total set of intensity measurements representing

the screened object, and the system indicates the presence of such an object. Embodiments of the invention are arranged to detect such offensive objects regardless of the orientation of the object (for example by screening offensive objects in a number of positions and orientations and successively comparing measurements for each subsequently screened person or object with measurements from each of these screenings). Embodiments can be arranged to detect any of a number of offensive objects and to indicate which object is detected and whereabouts on the screened person/object.

Embodiments of the invention may be incorporated into a number of different security systems depending on which type of detection is required. Figure 4a shows a security booth embodying the invention. In this case the entrance to a security area is through the booth. A personal identity card must be inserted into card reader 15 and an associated code number correctly manually entered on keyboard 16 before the booth entrance door 20 will open. The person is mapped by the aerial array 1 as they walk through the booth and processor 30 compares the obtained intensity measurements with the stored measurements for the relevant identity code. If the person is carrying the same metal as usual the green light 22 will be lit and the exit door 21 to the booth opened. If not the person will be trapped in the booth until the system operator ascertains the reason for the discrepancy. Type II detection can also be carried out in this system.

Figure 4b shows a metal detector for Type II detection only, e.g. for an airport check-in. The processor 30 can be arranged to operate an alarm buzzer or light 25 to alert the system operator to the presence of an offensive object e.g. a firearm, or a display screen may be used to display the location of the offensive object

on the screened person/object.

Figure 5 illustrates diammatrically one arrangement for carrying out the mapping sequences in the embodiment of Figure 4a. This embodiment comprises an array of sixteen dipole aerials 1 each of length $\lambda/2$ and arranged in two facing banks of eight aerials. A processor 30 controls the screening process, combining the functions of controlling the transmit/receive mode of each aerial, processing and comparing the sets of intensity measurements.

When the screening process is initiated, the processor 30 sends a control signal in the form of a 4-bit word to a transmit multiplexer 7 and simultaneously sends a 4-bit control signal to receive multiplexer 8 which multiplexers operate the sequential switching of the aerials in the array via circulators 4. The processor instructs the transmit multiplexer 7 so that aerial 1a will transmit signals at 4GHz, supplied by the oscillator 6, for a set period of time and then the aerial 1b will transmit for the set period of time and so on until all the aerial have transmitted . The processor instructs the receive multiplexer 8 to successively measure the received signals at aerials 1b to 1p while aerial 1a is transmitting, then to successively measure the received signals at aerials 1a, 1c to 1p while the aerial 1b is transmitting and so on until all of the aerials have transmitted.

The received signals pass from the receive multiplexer 8 to a modulating circuit, an amplifier 16 and a detection circuit. The frequency of the local oscillator 14 in the modulating circuit is chosen so that an intermediate frequency of roughly 30MHz will be output from the mixer 15. The amplitude of each amplified modulated received signal is measured by a detector 17 and converted to an 8-bit data word by an analogue to digital converter 18. The successive received signals, in the form of 8-bit

words, are fed to the processor 30 where they are held in a memory.

When one complete mapping sequence has been carried out the processor moves on to processing and comparison functions. The processor already has stored signals in memory representing the set of received signals for this particular screened object/person obtained at an earlier time. Comparison of the two sets of received signals is carried out. If the processor finds a discrepancy between the two sets of signals it activates display 35 and a warning signal is displayed. The processor may also be arranged to calculate the location of the object causing the discrepancy and output this location to the display.

If Type II detection is also to be carried out the processor will have further stored signals representing at least one offensive metallic object in memory. These also are compared with the set of received signals from the screened object. If the comparison indicates that the offensive object is present in the screened object then the processor activates the display 35 to display a warning signal. The location of the offensive object may also be outputted to the display.

Figure 5 only indicates one arrangement for putting the invention into effect. Many different circuits may be used in practice. Considerable variation is also possible in the processing and comparison of the sets of received and stored signals. Embodiments of the invention need not use all of the received signals in the comparisons, nor need the comparisons be arranged to look for an exactly perfect match of signals. These parameters may be varied to speed up the processing time and to alter the detection requirements of the whole system. For example an embodiment of the invention would have a shorter processing time where only the received signals from the 5 nearest neighbours to each transmitting aerial are processed.

Equally one could monitor all received signals for the one signal which is most different from the other received signals and use that to indicate which other signals should be processed.

Also in another embodiment the number of aerials transmitting at one time could be increased at certain points during the mapping sequence, since radiation from widely separated aerials will not interfere appreciably.

Although the features of the invention have been described with reference to embodiments used in metal detection for security purposes the invention is of wide application as stated above. Embodiments for the detection of particular types of material other than metals, such as gall stones, use electromagnetic radiation at a different range of frequencies to those used in the embodiments discussed earlier. Furthermore the geometry of the aerial array will differ from those described above in embodiments used for mapping mineral seams or locating burried pipes.

CLAIMS:

1. A method of selectively detecting objects comprising:

transmitting electromagnetic radiation into a predetermined detection region, detecting a parameter of the electromagnetic radiation at a plurality of spatially separated locations in the detection region, producing signals indicative of the values of the detected parameter, and processing said signals to produce further signals representative of the contents of the detection region.

2. Detection apparatus comprising:

a plurality of aerials operable in a transmitting and in a receiving mode and arranged to define a detection region, a source of electromagnetic oscillations, connected switchably to each of the aerials, control means for determining in which mode each of the aerials is to operate at a particular time and for connecting a selected one of the aerials to the source of electromagnetic oscillation, monitor means for producing signals indicative of a parameter of the electromagnetic radiation received by each aerial in the receiving mode, and processing means for producing further signals representative of the contents of the detection region from the output of the monitor means.

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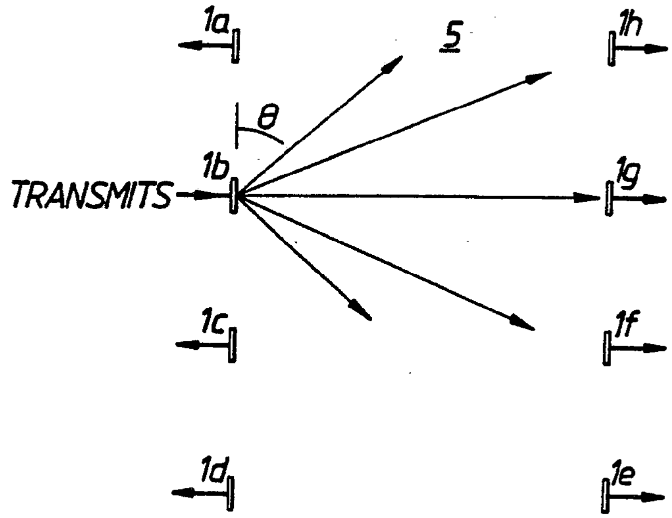

FIG. 1a.

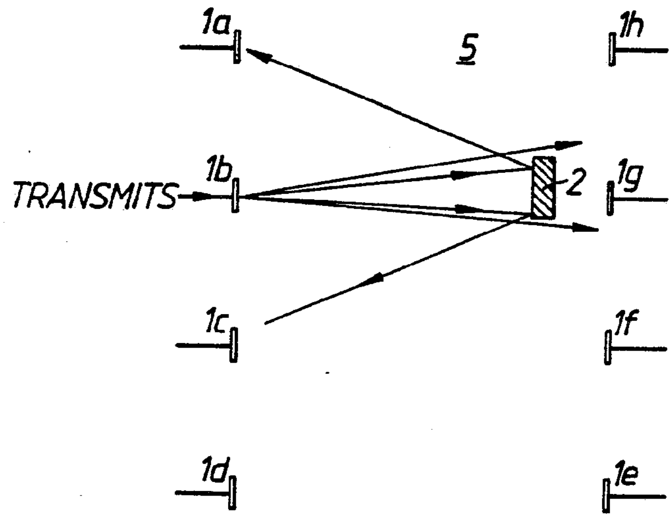

FIG. 1b.

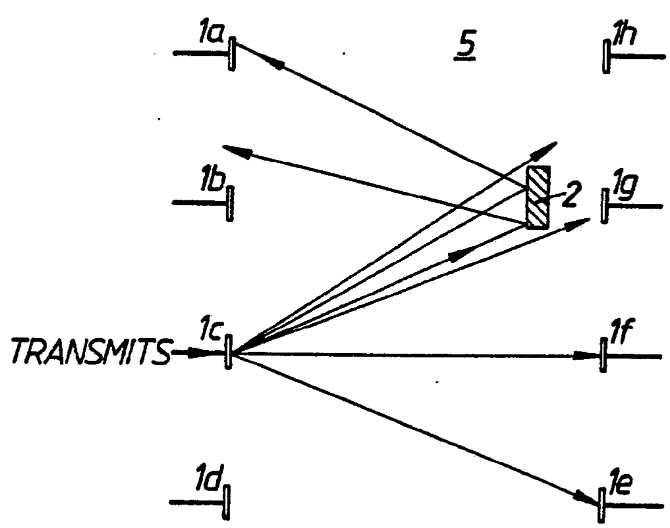

FIG. 1c.

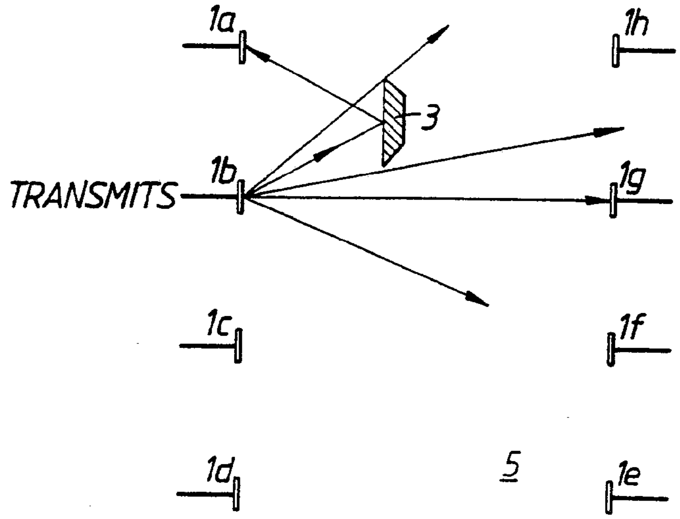

FIG. 2a.

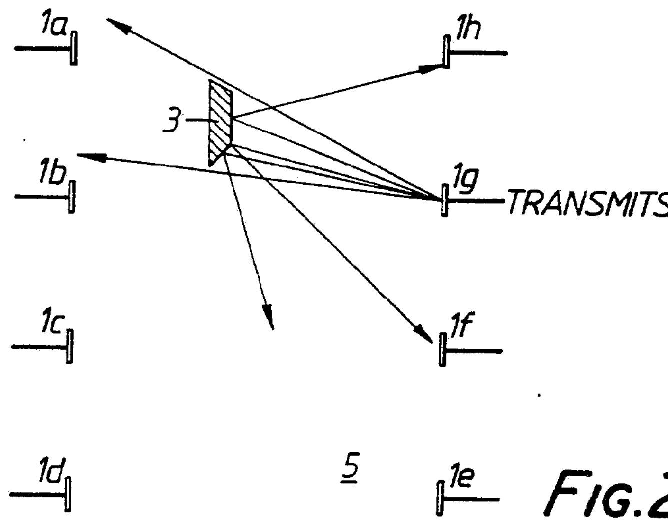

FIG. 2b.

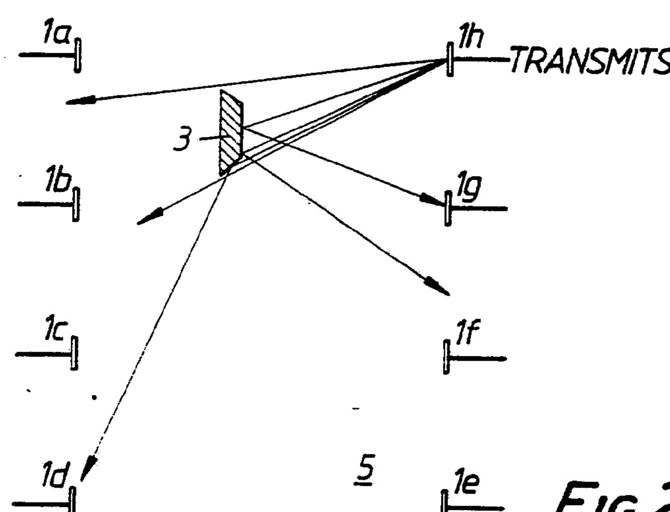

FIG. 2c.

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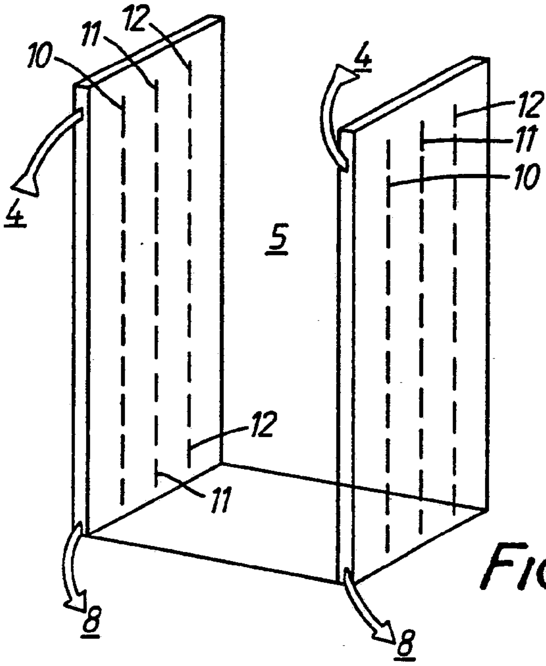

FIG. 3.

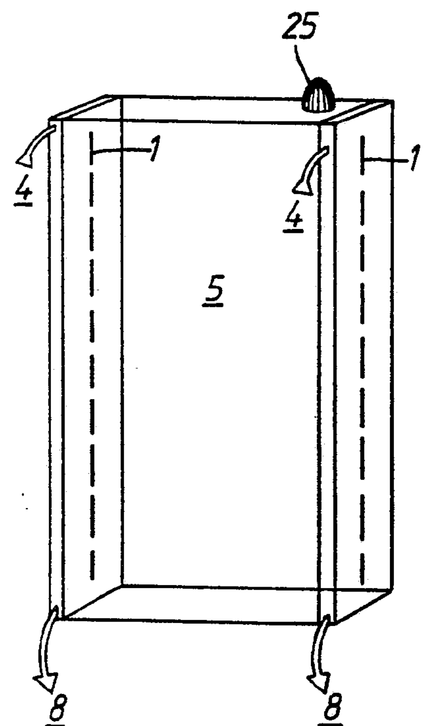

FIG. 4b.

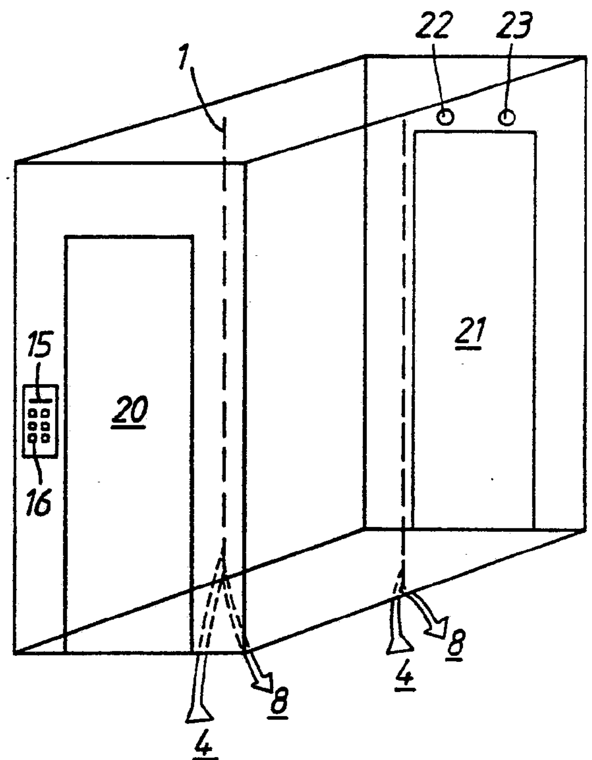

FIG. 4a.

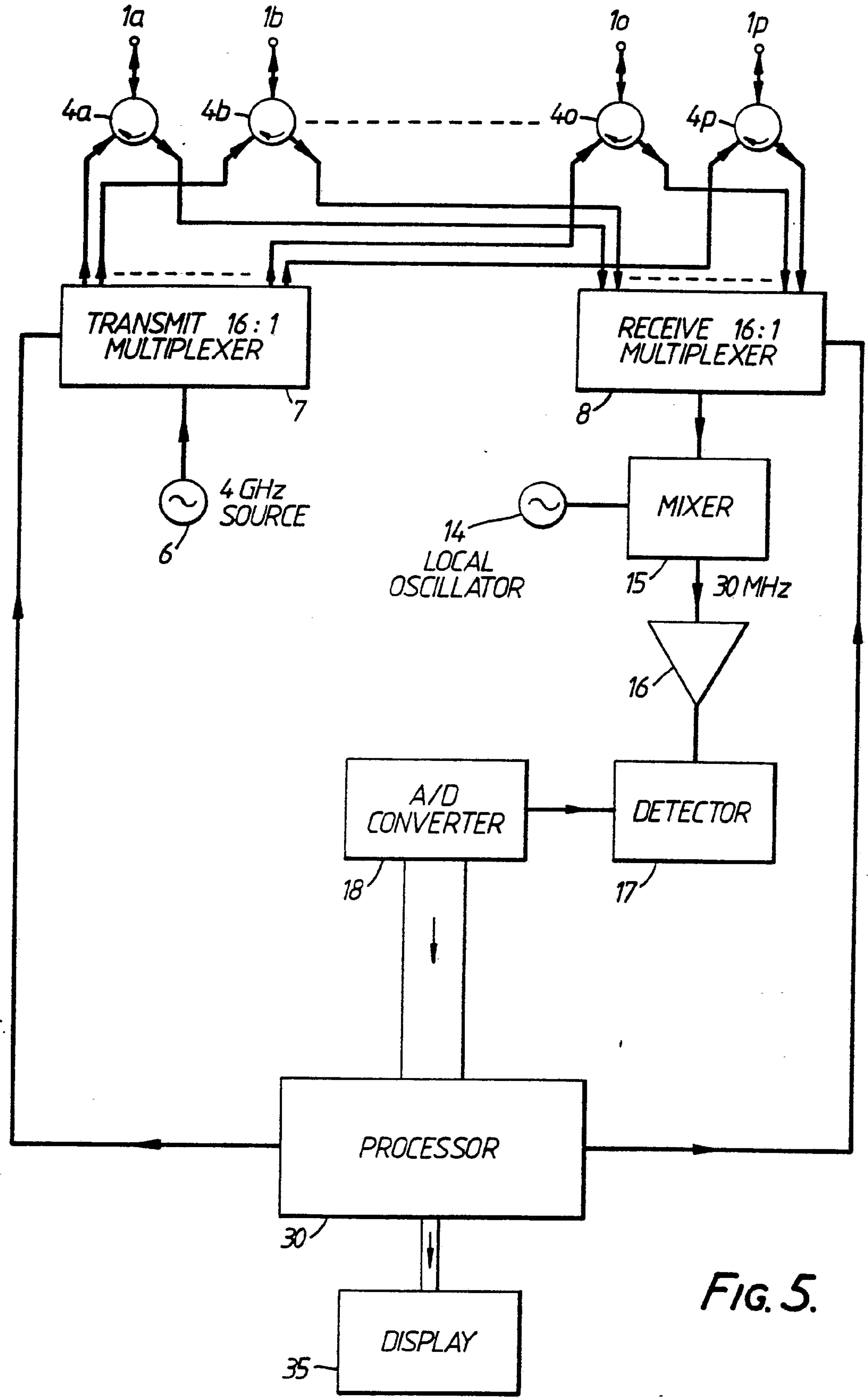
1a
1b
1o
1p
4a
4b
4o
4p
TRANSMIT 16 : 1 MULTIPLEXER
7
RECEIVE 16 : 1 MULTIPLEXER
8
4 GHz SOURCE
6
MIXER
14 LOCAL OSCILLATOR
15
30 MHz
16
A/D CONVERTER
18
DETECTOR
17
PROCESSOR
30
DISPLAY
35

FIG. 5.

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 88/00556

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC4: G 01 V 3/12, G 01 S 13/88

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC4	G 01 S, G 01 V, G 08 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X A	DE, A, 2161138 (TIEFENBACH) 14 June 1973, see page 4, line 22 - page 6, line 24 --	1 2
X A	DE, A, 2326797 (HEYTOW) 6 December 1973, see page 7, line 4 - line 22 --	1 2
X A	DE, A, 3421066 (HEIMANN GMBH) 2 January 1986, see page 5, line 4 - line 37 --	1 2
E	GB, A, 2199715 (JENNINGS) 13 July 1988, see the whole document -- --------	1,2

* Special categories of cited documents: [10]

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
27th February 1989	17 MAR 1989
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	P.C.G. VAN DER PUTTEN

Form PCT/ISA/210 (second sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. PCT/GB 88/00556

SA 23306

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The members are as contained in the European Patent Office EDP file on 12/01/89
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-A- 2161138	14/06/73	NONE	
DE-A- 2326797	06/12/73	FR-A-B- 2189756	25/01/74
		AU-D- 56205/73	28/11/74
		GB-A- 1436900	26/05/76
		JP-A- 49063462	19/06/74
		CA-A- 1080821	01/07/80
DE-A- 3421066	02/01/86	NONE	
GB-A- 2199715	13/07/88	NONE	

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